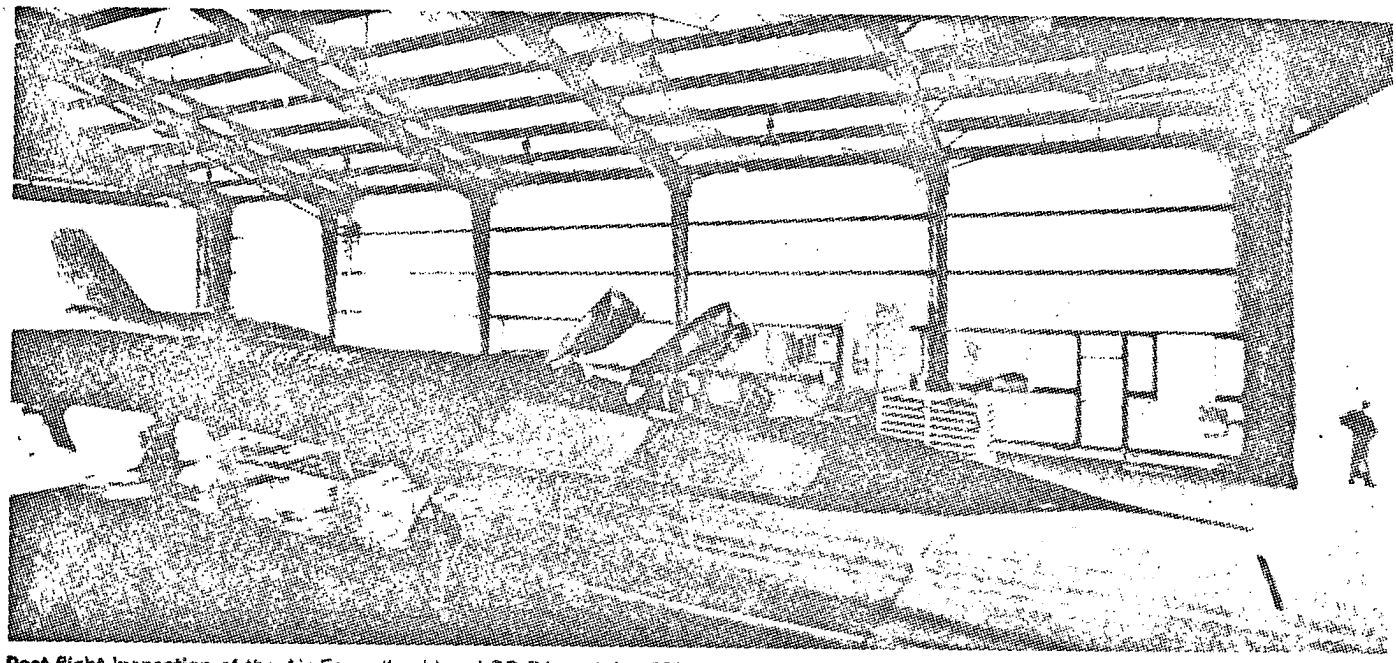


Post-flight inspection of the Air Force/Lockheed SR-71 contains 650 items. It takes five specialists about 6 hr. to inspect the aircraft.

Aeronautical Engineering

SR-71 Imposes Burden On Maintenance Units

Beale AFB, Calif.—Extreme operating environment and the unique structure, propulsion and subsystems of the U. S. Air Force/Lockheed SR-71 strategic reconnaissance aircraft impose a heavy maintenance burden on the units responsible for keeping SR-71s flying.

First Strategic Reconnaissance Sqdn. of the 9th Strategic Reconnaissance Wing is the only operational Strategic Air Command unit to operate the SR-71. Maintenance for the aircraft is provided by the 9th SRW, which also supports the Lockheed U-2, Northrop T-38 and Boeing KC-135 aircraft operated by other units of the wing.

Special Demands

The unique operational, structural and propulsion aspects of the SR-71 (see p. 46) impose special demands on the wing's maintenance organization that are not typical for other aircraft operated by the wing. In addition, the age of the aircraft is causing growing concerns about the availability of spares and vendors.

These concerns are offset to some extent by improvements in systems reliability with maturity, and by steady updates in the SR-71's systems with newer and generally more reliable components.

The unique aspects of SR-71 maintenance include several areas:

- **Structures**—Intense heating of the aircraft's skin at its Mach 3-plus cruise speeds imposes uncommon thermal stresses on the entire aircraft. The SR-71 structure consists of approximately 70% titanium and 30% composites to cope with this. Frequent extensive inspections are necessary because of the high thermal and aerodynamic stresses, and special tools must be used because of materials employed.

- **Propulsion**—Pratt & Whitney J58 bleed-bypass turbojet engines have special features such as automatic engine trimming, variable position inlet guide vanes, high flash point fuel and a chemical ignition system that demand an experience level beyond that of most maintenance personnel. In addition, engine performance is highly dependent on the satisfactory operation of a complex air inlet and exhaust system that is not linked to the engine physically. At cruise speeds, the inlets and exhaust nozzles generate almost 90% of the aircraft's thrust.

- **Systems**—Fuel, oil and hydraulics are all non-standard and require special heat-resistant characteristics not normally found in subsystems of this type. Special ground support equipment is necessary to handle these liquids. An on-board nitrogen-inerting system is necessary to reduce fire and explosion risks in fuel tanks, hydraulic lines and battery compartments.

- **Mission payloads**—Reconnaissance systems carried in the SR-71 are removed and replaced for each mission. Five different nose configurations are used to accommodate various payloads, and the nose section from the front firewall of the forward cockpit is considered part of the mission rather than the airframe package.

Maintenance requirements for the SR-71 are estimated to be in the hundreds of maintenance man-hours per flight hour because of these and other factors, compared with something in the vicinity of 30-40 maintenance man-hours per flight hour for aircraft such as the wing's Boeing KC-135 tankers.

Stringent Criteria

Inspection criteria for the SR-71 are the most stringent of any aircraft in the Air Force inventory, maintenance supervisors believe. Maintenance post-flight inspection on the KC-135 consists of seven checklist items, they said, while the SR-71 post-flight checklist carries about 650 items. Earlier, the list covered about 875 separate items, but experience and improvements have helped eliminate some of those.

It still takes an average of five structural specialists about 6 hr. to inspect an SR-71 after each flight, including an examination of every titanium and plastic spot weld on the top of the wings. Two propulsion specialists also spend several hours after each flight examining inlets, exhaust nozzles and the engines themselves.

In addition to these, more extensive inspections and maintenance actions are conducted every 25 hr. of flight time, and major inspections and repairs are executed every 100 and 200 hr.

The 100-hr. inspections normally take around 11 working days of 16 hr. each and are basically structures-oriented. This includes the engine inlets, which are part of the airframe rather than the engines. Any pending field-level modifications to

aircraft and syst[illegible] incorporated. Engines are not normally given heavy treatment during this cycle, although the last several SR-71s to pass through the inspection hangar for their 100-hr. check have had both engines removed for replacement.

Normally, the engines are removed and inspected only during the 200-hr. check, which is programed to take about 15 working days but normally takes closer to one month, according to wing maintenance personnel here. Every component in the aircraft—including the engines—is disassembled, inspected and may be replaced during the 200-hr. check.

This work normally is accomplished here at Beale by Air Force maintenance crews with assistance from contractor field service representatives.

About once every three years, the SR-71s are returned to Lockheed at Palmdale, Calif., for a complete teardown and overhaul. The J58 engines are returned to Pratt & Whitney for a complete overhaul after 600 hr. of operation.

Structural maintenance on the SR-71s is complicated by the special materials used and because the aircraft were essentially hand-made, with very few interchangeable jig-fit items. If a hole is accidentally poked in a titanium panel on one of the aircraft, it may be necessary to order a new panel from Lockheed by aircraft number rather than repairing the panel on site.

Extensive use of titanium in the SR-71 structure poses its own problems. Normal cadmium-plated tools cannot be used on titanium because of the corrosive effects of cadmium on titanium. Special tool kits must be kept for maintenance work on the SR-71s, and newly assigned maintenance personnel must be trained to use these tools.

Surface Temperatures

Because surface temperatures range from 400-1,200F on the SR-71 during high-speed flight, any screws or other fasteners removed from the aircraft are baked in an oven before being put back into the structure to prevent damage due to expansion and seizure caused by in-flight heating.

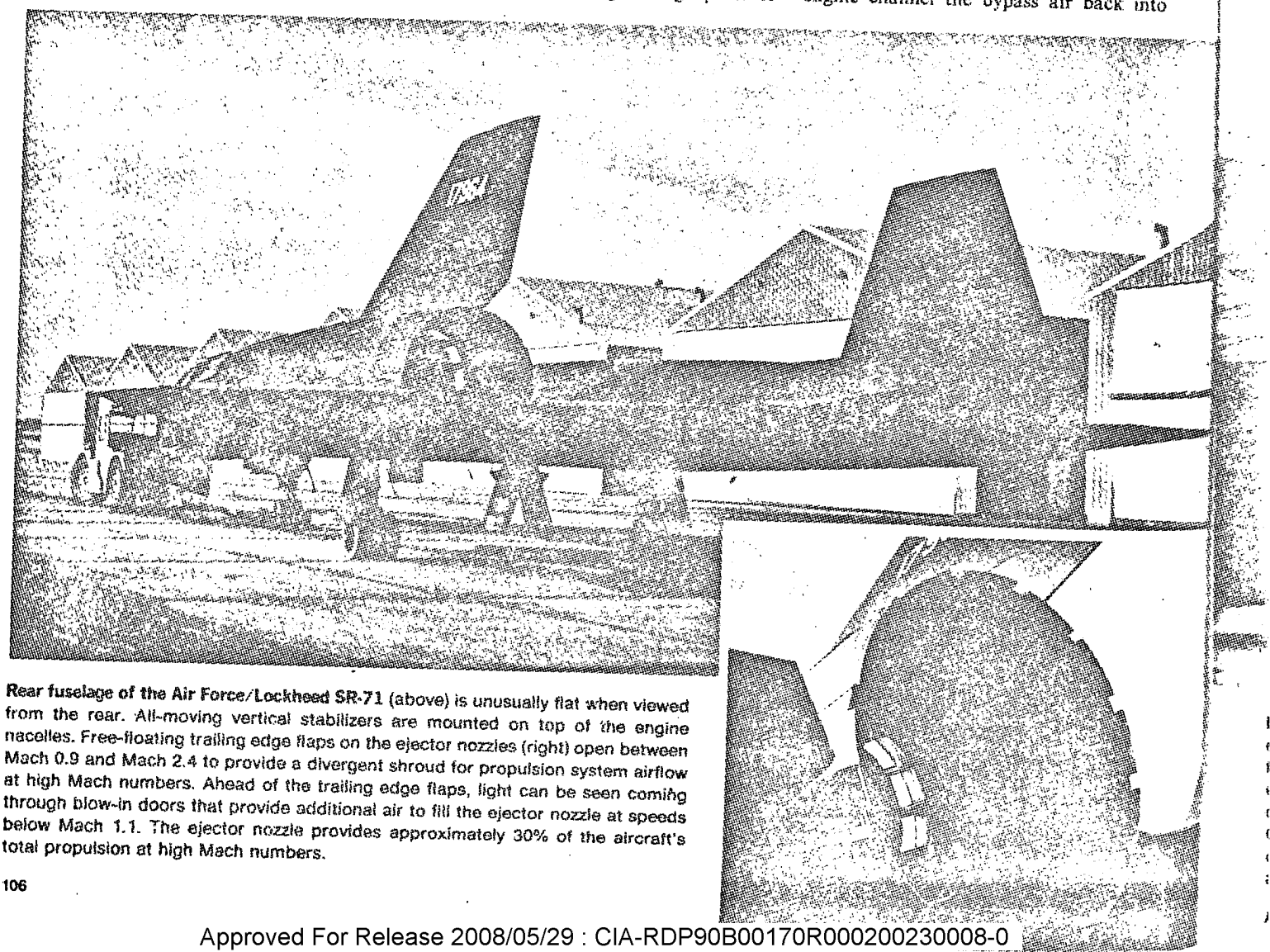
Fuel bladders are not used in the SR-71, and the aircraft's skin forms the upper and lower walls of its six internal fuel cells. It is impossible to keep the tanks sealed properly because of the significant structural expansion and contraction that takes place on each flight due to thermodynamic heating and cooling. Maintenance procedures call for resealing the tanks every 200 hr., and even then there is a considerable amount of fuel leakage. Large pools of JP-7 fuel beneath the SR-71s are common when the aircraft are parked in their individual shelters.

Additionally, the JP-7 has a tendency to delaminate the plastic honeycomb skin structure of the SR-71 when it leaks out of the fuel tanks and into other internal areas of the aircraft and is allowed to collect for sustained periods.

Inlets present a special hardship for structural specialists maintaining the SR-71s. Because of the limited space, any structural repair work in inlet duct areas—even with the spikes removed—often means removing the engines first so technicians can work from the back of the ducts. The spikes are pulled during every 50-hr. check so that the inlet structure can be inspected.

The J58 engines powering the SR-71 have their own unique aspects, including the capability to operate continuously at maximum afterburning for high-altitude, high-Mach flight. Use of titanium compressor and turbine blades contributes to this sustained high-temperature operating capability.

A bleed bypass from the fourth stage compressor bleeds air from the compressor at high Mach numbers to provide increased compressor stall margin. Several ducts around the circumference of the engine channel the bypass air back into



Rear fuselage of the Air Force/Lockheed SR-71 (above) is unusually flat when viewed from the rear. All-moving vertical stabilizers are mounted on top of the engine nacelles. Free-floating trailing edge flaps on the ejector nozzles (right) open between Mach 0.9 and Mach 2.4 to provide a divergent shroud for propulsion system airflow at high Mach numbers. Ahead of the trailing edge flaps, light can be seen coming through blow-in doors that provide additional air to fill the ejector nozzle at speeds below Mach 1.1. The ejector nozzle provides approximately 30% of the aircraft's total propulsion at high Mach numbers.

the engine ahead of the afterburner, where it is used for cooling and thrust augmentation.

The J58s use a special oil that becomes a near-solid at colder temperatures, and must be preheated to 30C (86F) before each flight. The oil is never discarded but is returned to the manufacturer for reprocessing each time it is drained from an engine.

Changing the engines on the SR-71 involves raising the wings of the aircraft in much the same manner naval aircraft have their wings folded upward for space saving on aircraft carriers. Even with the outer wing and part of the nacelle out of the way, removing and replacing an engine in the SR-71 is a complex task that requires a minimum of five technicians and an elaborate, hydraulically controlled dolly.

The dolly aids the technicians in working to the close tolerances and following the circuitous route the engine must travel out of and back into the nacelle. Senior maintenance technicians estimate that 6-9 hr. is required to install and connect a J58 in the SR-71.

Like the engine oil, a special fluid is also used in the SR-71's hydraulic systems. Elaborate measures must be taken to keep oxygen out of the fluid, because at the high temperatures reached during high-Mach flight in the SR-71, the fluid would burn and cause varnishing inside the hydraulic systems, ultimately leading to servo and valve malfunctions in the systems. Where hydraulic fluid temperatures normally might reach 100-150 or 160F in a typical high-performance fighter, hydraulic fluid temperatures in the SR-71 range 400-650F during high-speed cruise.

To prevent burning and varnishing, the SR-71's hydraulic fluid must be kept pressurized with nitrogen—both while in storage in barrels and when in the aircraft's hydraulic systems—to keep out oxygen. Elaborate anticontamination and oxygen-monitoring procedures are followed from the time a 55-gal. drum of the fluid is received until it is drained from the aircraft at the end of its useful life.

Realistic Trouble-Shooting

In order to duplicate in-flight circumstances when trouble-shooting for hydraulic system malfunctions, a special hydraulic cart referred to as a "hot gig" is used to heat the fluid to operating temperatures while the aircraft is on the ground. Maintenance technicians said hydraulic leaks that normally would not be detected on the ground can be found using the hot gigs because small puffs of vaporized hydraulic fluid are emitted from leaks when the fluid reaches high temperatures.

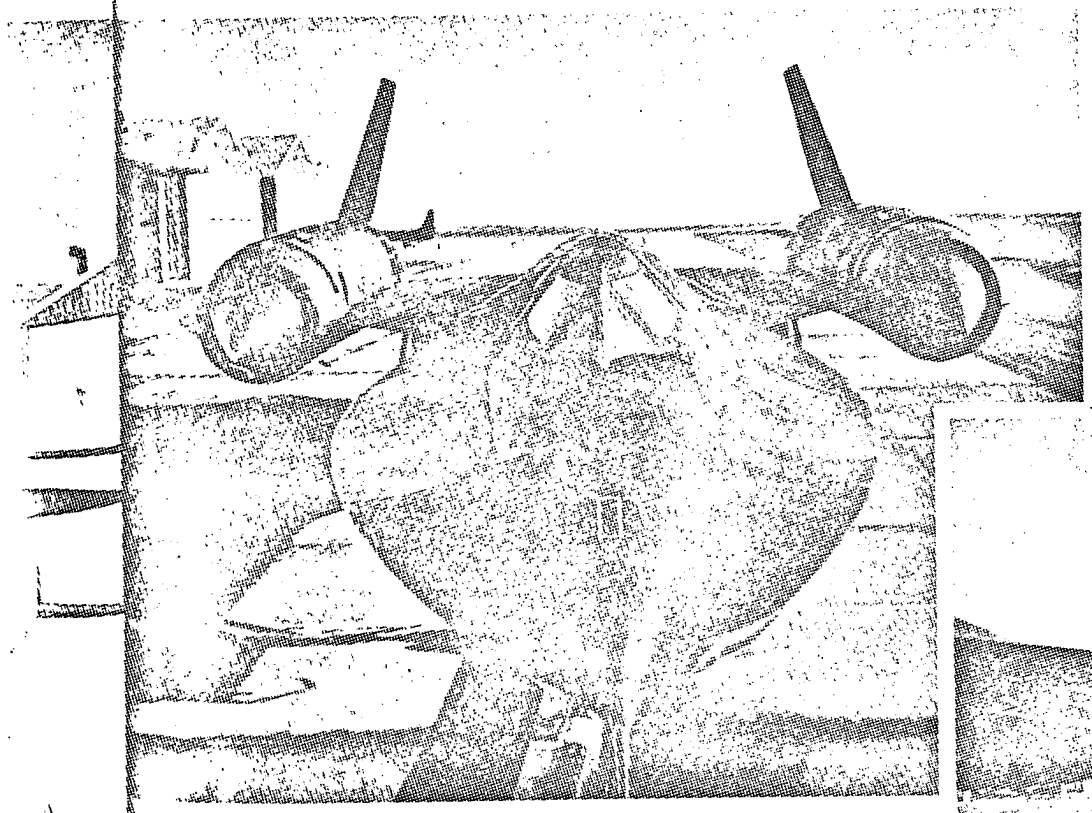
The high operating temperatures pose other special considerations. Standard O-ring seals cannot be used in the hydraulic system because of the heat, so special metal rings or metal-to-metal sealings must be used instead. Non-standard fittings are used throughout the hydraulic systems for better sealing under the extreme heat conditions.

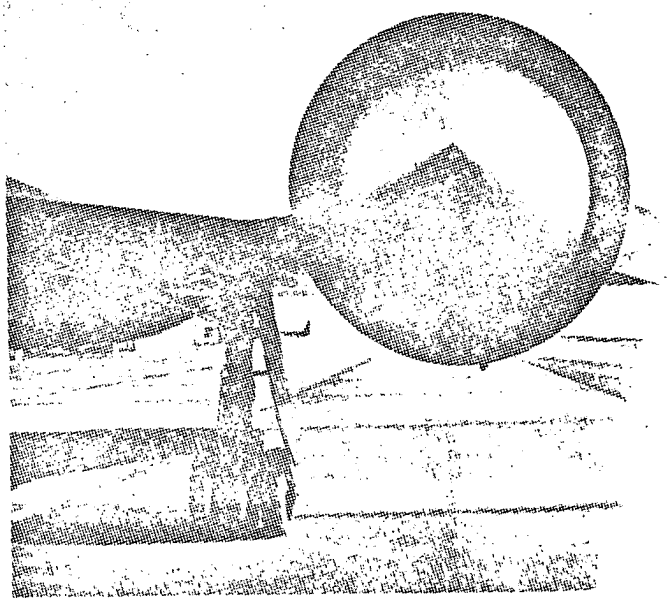
Numerous other non-standard maintenance procedures are used on the SR-71, including:

- Standard grease cannot be used for lubrication on the aircraft because of the operating temperatures, and a silicon-based instrument transducer lubricant is used instead for those fixtures requiring lubrication.
- Insulation is used extensively throughout the SR-71 to protect critical systems, wiring and fluid lines from the heat. This insulation must be removed when fuel leaks develop, and replacement is a difficult and time-consuming chore, according to maintenance supervisors here.
- Silver-zinc batteries used for emergency power must be removed from the aircraft for recharging after every flight. The recharging process takes two days. In the aircraft, the batteries are sealed and pressurized with nitrogen to reduce the possibilities of explosion at high temperatures.
- Electrical connectors always have been a high maintenance item because of the effects of heat and have been gold-plated to reduce heat damage.

Maintenance supervisors have learned how to contend with most of these problems over the years, and the prime concerns currently center on supply and personnel shortages rather than unique maintenance procedures. Many of the original SR-71 suppliers have either gone out of business or are no longer producing the items they once supplied. The J58 engines are a prime example.

As a result, the Air Force is contracting





Front view of the SR-71A (above) shows the chines, which flare outward on each side of the SR-71 fuselage, providing added lift and directional stability for the aircraft, and the placement of the two Pratt & Whitney J58 turbojet engines in the wings. All-moving vertical stabilizers are canted inward 15 deg. to minimize the rolling moment due to sideslip or vertical deflection. Cone-shaped inlet spike in each engine nacelle (right) moves aft 25 in. during high-speed, high-altitude cruise to capture more airflow and slow the airflow before it enters the engine.

out for many of its spares for the SR-71 through the SR-71 Advanced System Program Office (ASPO) at Norton AFB, Calif.

This has not resolved fully the problem of engine spare parts shortages and the declining number of available engines for the SR-71. Several engines currently are on extended hold in maintenance shops here because of parts shortages, and one engine recently was reinstalled in an SR-71 after spending more than a year in the maintenance shop because of parts shortages.

Inspection Turnaround

Five years ago, engines coming into the shop for major inspections were being turned out in about 15 days maximum, according to maintenance supervisors, even though inspection criteria were more stringent then. Currently, the time required to turn one of the engines around ranges from one month to six weeks, they said, primarily because of spares supplies.

On the personnel side, the extended training required for SR-71 maintenance technicians, low retention rates and Air Force requirements for qualified personnel in other areas all have combined to threaten the continuity of SR-71 maintenance activities. Four-year enlistees come directly from Air Force technical schools and then must undergo 18-24 months of additional training here before they are considered qualified to work without constant supervision. This leaves only about 18 months during which these technicians can be used before they leave the service.

The resultant lower experience levels have contributed to an increase in the maintenance man-hours per SR-71 flight hour, maintenance supervisors said.

Reliability Improvements

Steady improvements in the reliability of SR-71 systems and a heavy dependence on contractor-provided field service representatives have helped counteract many of these problems, senior officers here said. On the reliability side, for example, the astro navigation system has a 99% reliability rate, they said—far above its earlier performance record.

Civilian field service representatives, who generally have been phased out of most other branches of the military services, have become critical to the SR-71 maintenance effort.

"They have become extremely important to us and are becoming more integral to our entire maintenance operation," a wing maintenance officer here said. Among other advantages, the field service representatives provide the much-needed continuity in SR-71 maintenance operations; they are more versatile than their military counterparts; they present fewer personal problems, and they are less expensive than military maintenance specialists in the long run, according to 9th SRW officers. □